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The Use and Performance of Alternative Contracting Methods on Small Highway Construction Projects

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Abstract

Highway agencies choose alternative project delivery methods to save time and control costs. Large, high-profile, design-build and construction manager/general contractor projects give the impression that alternative project delivery methods are only applicable to larger, more complex projects. This research reports on a sample of 291 US highway projects, more than half of which are under $20 million in final cost. The study provides empirical evidence of how alternative project delivery methods relate to small project successes, specifically design-build successes. The data for this study includes design-bid-build, design-build, and construction manager/general contractor highway projects completed between 2004 and 2015. The results are useful for governmental agencies, suggesting time savings may be achieved on small projects through the use of alternative contracting methods with no negative impacts on cost growth.

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Keywords: Project delivery; small projects; highway construction; performance factors; design-build; construction manager/general contractor

1. Introduction

The Construction Industry Institute estimated that 50 percent of all public and private construction industry capital budgets are being spent on smaller projects [1]. The database collected for the present study suggests that highway construction projects mirror this frequency of small projects, having sixty percent of the projects with a contract award

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value less than $20 million. With small projects accounting for such a large portion of the highway construction sector, research concerning the processes being used to deliver these projects and their success is paramount.

The common perception in the highway construction industry is that the delivery method best fit for small projects is the traditional design-bid-build (D-B-B) and that alternative contracting methods (ACMs) such as design-build (D-B) and construction manager/general contractor (CM/GC) are only appropriate for large-scale projects [2, 3]. The results from this study challenge this perception, suggesting ACMs are being used on small projects, achieving similar time and cost growth mitigation benefits attributed to larger projects.

1.1. History of Highway Project Delivery Systems

The focus of this research is to determine the frequency of use that differing project delivery methods, D-B-B, CM/GC, and D-B, are experiencing for projects under $20M. The characteristics and processes inherent within each project delivery method result in preconceived notions of their ability to be used on small projects. D-B-B is the oldest of these modern construction delivery models, solidified by the Miller Act of 1935 [2]. With D-B-B, the owner separates engineering and construction. The agency fully develops the drawings and bears the full design development risk. Based on the literature, D-B-B is the preferred method for projects of low complexity and risk [3].

As opposed to the almost century-old D-B-B method, D-B and CM/GC are new delivery models. D-B and CM/GC's nationwide use within the transportation sector began with the enactment of FHWA Special Experimental Project Number 14 (SEP-14) – Innovative Contracting in 1990 [4]. SEP-14 was enacted to enable state transportation agencies to use a variety of ACMs, testing and evaluating their use. Under the SEP-14 program, approximately 300 projects were proposed for D-B contracting between 1995 and 2002 and 25 projects have been proposed for CM/GC contracting between 2003 and 2015 [5].

Although SEP-14 opened the door to the use of CM/GC, CM/GC's growth within highway was relatively slow [6]. To facilitate greater CM/GC use, the Moving Ahead for Progress in the 21st Century Act (MAP-21) was enacted in July 2012 removing the requirement for state DOTs to receive approval to use the CM/GC delivery under SEP-14 [7]. Based on a FHWA Division Office Survey in 2012, Alaska, Arizona, California, Colorado, Connecticut, Florida, Idaho, Michigan, Minnesota, New Mexico, Oregon, and Utah have full authority to use CM/GC and Maine, Maryland, Nevada, Texas, and Washington have a limited authority to use CM/GC [8].

With CM/GC, the owner contracts with a construction manager (CM) early on in the design development, contractually transferring the risk for the final cost and time of construction. After design work is complete (or essentially complete), a guaranteed maximum price (GMP) is negotiated with the CM. If negotiations are successful, the CM essentially becomes the general contractor (GC), hence CM/GC. Having the contractor involved with the design process, the agency benefits from contractor ingenuity and contractually transfers the risk for the final cost and time of construction. CM/GC is well-suited for high risk, complex projects and is chosen strongly based off of monetary size and budgetary control concerns [6].

D-B did not have the growth issues CM/GC experienced under SEP-14. The positive results of D-B projects developed and evaluated under SEP-14 led to the the D-B Contracting Final Rule which was published in the Federal Register in 2002. The D-B Contracting Final Rule increased the D-B ease of use in the following ways: allowing use of D-B contracting on both qualified and non-qualified projects, allowing stipends for unsuccessful D-B proposers, eliminated minimum prime contractor participation restrictions, allowing the splitting of contracts, and suggesting many best practices discovered under SEP-14 [9]. The FHWA further continued to improve their D-B program, enacting section 1503 of SAFETEA-LU on August 14, 2007 which eliminated dollar thresholds for qualified projects and allowed agencies to issue D-B RFP documents, award contracts, and issue notices-to-proceed for preliminary design work prior to the conclusion of the National Environmental Policy Act (NEPA) process [10]. Based on FHWA Division Office Survey in 2012 only Oklahoma, Nebraska, and Iowa lack use of D-B for transportation projects [8].

With D-B, a single entity contracted to perform both design and construction services. D-B transference of risk is the greatest of the three models as the agency presents performance requirements rather than plan specifications and transfers design completion and control to the contractor [3]. D-B selection processes is either a fixed-price, low bid (LB) or qualifications based, best value (BV) award. D-B/LB is characterized by a high level of design completion at time of procurement, allowing the agency to retain control over the scope while still transferring the design risk to the contractor. Alternatively, D-B/BV is characterized by a low level of design completion at time of procurement, allowing the agency to more fully transfer the design risk to the contractor [11]. D-B suitability is thought to be strongly correlated to the size of the project, and is generally used for more complex projects than D-B-B and less complex projects than CM/GC [3].

As stated, D-B and CM/GC have experienced growth and acceptance as highway construction delivery methods and are no longer seen as experimental but rather viable options that must always be considered. Currently, 17 states have at least limited authority to use CM/GC and all but three states use D-B for transportation projects [8]. All 26 states involved with this study submitted data for D-B projects, agreeing with the nationwide acceptance and use of D-B. Only seven states involved with this study submitted data for CM/GC projects, several being the state's first or second CM/GC project. This suggests that although CM/GC is no longer experimental, it is not commonly used.

D-B's national use and expedited growth is due to it's proven ability to reduce schedule duration and potential for cost savings in comparison to D-B-B [3, 12 - 17]. Previous research has proven CM/GC's ability to reduce schedule duration but has not yet proven a superior cost mitigation delivery method in comparison to D-B-B [4]. This may be the cause for its somewhat stagnated growth.

1.2. Project Size and Highway Project Delivery Systems

Previous research has found that the major factor in agencies choice of CM/GC and D-B's suitability for a project is the monetary size of a project [3, 6]. This is further illustrated by the use of ACM on high profile, mega-projects such as the Foothill/Eastern Transportation Corridor in southern California, Utah I15, and the Colorado TREX and the those performed under recently passed Caltrans CM/GC Pilot Project and D-B Demonstrations Program.

The Foothill/Eastern Transportation Corridor project is one of the first projects in the nation, and the first in California, to use D-B as a delivery method under the SEP-14 legislation. The Foothill/Eastern Transportation Corridor was a toll road meant to mitigate the I-5 and I-405 congestion to Orange County, California in the early 90's. The total project cost was $1.8 billion and was financed using a Public-Private Partnership [18]. D-B was chosen for this mega-project mainly due to the stipulation that the allocation of design and construction risk would be shared between the agency and contractor [19].

The success of the The Foothill/Eastern Transportation Corridor project gave the Utah Department of Transportation (UDOT) sufficient confidence in the D-B model to use it as a delivery method for the I-15 reconstruction project, once again under the SEP-14 legislation. The I-15 restructuring project included rebuilding 17 miles of 10-12 lanes of interstate along I-15 with a $1.4 billion D-B contract. D-B was chosen for this mega-project mainly due to the time restraints of the projects caused by 2002 Salt Lake City, Utah Winter Olympics [20].

The Transportation Expansion (T-REX) Project the most successful highest profile example of D-B's use for a mega-project. The T-REX total project value was $1.7 billion and consisted of adding 19.7 miles of light rail; thirteen light rail stations; highway improvements including adding High Occupancy Vehicle lanes; replacing 13 bridges; and repairing nine bridges. D-B was chosen for T-REX in an attempt to meet the budget and schedule while delivering a quality project driven by contractor ingenuity [21]. The use of D-B use resulted in the project being completed 22 months ahead of schedule, 3.2% under budget, and receiving over three dozen national and local awards received as of May 2007 [21, 22]. The project sponsors estimated that T-REX, which took approximately 6 years to complete, would have taken 20 years or more to construct under a standard D-B-B process [22].

The Caltrans CM/GC Pilot Program, created in 2012, and D-B Demonstration Program Projects, created in 2009, depict the modern-day opinion of the use of ACMs in highway construction. All of the projects selected for the CM/GC Pilot Program are over $50 million and 90% of the projects selected for the D-B Demonstration Program Projects Program are over $20 million with an average of $211 million [23, 24]. These project award values suggest that ACMs are still typically seen as only being viable for large projects.

It should be noted that ACMs being used only on large projects is not a universally held belief. For example, the first D-B projects, performed as early as 1987 by Florida Department of Transportation (FDOT), were all small projects. The first 11 D-B projects accumulating a total value of $31 million in project awards [25]. The database for this study also shows that 70% of FDOT's D-B projects are under $20 million and 61% of all of UDOT's CM/GC projects are under $22 million. These examples of ACMs being used on small projects can be attributed to the initial testing of D-B as a delivery model and the matured ACM markets found in Florida and Utah.

2. Research Methodology and Hypotheses

The focus of this research is to explore the commonly held belief that only the traditional D-B-B is being used for small projects. This commonly held belief is proven by the industry's actions both past and present; the industry's historical of ACMs on high profile mega-projects and current use of ACMs on projects averaging \$211 million under the newly enacted Caltrans CM/GC and D-B legislations [18 - 24]. Furthermore, it is the authors' professional experience in their research within the transportation sector and discussions with FHWA, DOT, and contractor representatives that ACMs are not generally considered for projects under \$20 million in award value.

No current publications discuss ACM cost and schedule performance specifically on small projects. An exploration of small project performance will add to the general body of knowledge for highway design construction. The authors set out to explore both the the frequently CM/GC, D-B/LB, and D-B/BV are being used on projects with award values less than \$20 million, less than \$10 million, and less than \$5 million and if using ACMs on projects less than \$20 million cause negative impacts to the performance metrics, cost and schedule growth in this research.

3. Data Collection and Method of Analysis

The database used for this paper is part of a national study on the risks and benefits of ACMs for highway construction [26]. This study collected performance data from 291 US highway projects that were completed between 2004 and 2015. These projects were collected from DOTs and the FHWA Office of Federal Lands Highway. The data collection involved 26 states who were determined to be using ACMs through a national survey of all DOTs. The D-B and the CM/GC projects were randomly selected from DOTs which actively engaged in those delivery methods. The D-B-B projects, were sampled to be similar in location, size, and time of award to the D-B and CM/GC projects.

The data from each project was obtained through a questionnaire that was administered to the agency's project representative by email with phone correspondences as required for data verification. The quality of the data was ensured through rigorous quality control techniques as presented by Rahm et al [27]. The data used from the questionnaire for this research is as follows: project delivery method, planned project duration, actual project duration, contract award cost, and final cost. All costs were converted to June, 2015 dollars using the appropriate National Highway Construction Cost Index (NHCCI) time modifier [28].

The 291 survey responses were "cleaned" removing projects which did not respond, illogical response data, and all cost growth extreme outliers. Subsequent to cleaning the data, 275 US highway projects are available for cost growth analysis, 107 for schedule growth analysis and 183 for project intensity analysis. The 275 projects include the following descriptive statistics:

- *Project Delivery Types*: 130 D-B-B, 37 D-B/LB, 77 D-B/BV, 31 CM/GC
- *Project Award Value:* \$69k to \$358M
- *Cost Growth:* -22% to 38%
- *Schedule Growth:* -34% to 90%
- *Project Duration:* 130 to 2,859 days

Please see Table 1 for the detailed descriptive statistics of the award values arranged by project delivery type. The cost growth, project schedule growth, and project intensity of each project was calculated using the equations seen below.

$$\text{Cost Growth} = (\text{Final Contract Cost} - \text{Contract Award Cost}) / (\text{Contract Award Cost}) \quad (1)$$

$$\text{Project Schedule Growth} = (\text{Actual Project Duration} - \text{Planned Project Duration}) / (\text{Actual Project Duration}) \quad (2)$$

$$\text{Construction Intensity} = (\text{Final Contract Cost}) / (\text{Actual Construction Duration}) \quad (3)$$

The resulting project cost growth, schedule growth, and project intensity were then separated and averaged by the four project delivery methods D-B-B, D-B/LB, D-B/BV, and CM/GC. Using MVPstats program, each descriptive statistic was tested for normality within each project delivery method. Subsequently, pairwise tests for dispersion (equal variance) were performed on the categories of change orders within and across the project delivery methods. Finally, appropriate tests for differences in the means of the cost growth, schedule growth, and project intensity orders among the project delivery methods were performed, i.e. F or ADMn-1 and variance equal or unequal t-tests as applicable [29].

4. Results and discussions

Subject matter experts, previous research, the historical use of ACMs on high profile projects, and the defining characteristics of ACMs all agree that the major factor in agencies choice of CM/GC and D-B is suitability for a project is the monetary size of a project. If this were true, the resultant data would show little use of CM/GC and D-B for contract awards under $20 million and even less on contract awards under $10 million. It would be expected that the average contract award values would be in the $100 millions. Finally, it would be expected that any ACMs that were used for projects under $20 million would have poor cost and schedule performance.

The data found in Tables 1, 2, and 3 greatly contrast these expectations. Table 1, shows that CM/GC and D-B/BV are nearly half of the time used for small projects, which is in disagreement to common perception. Table 1 also shows that CM/GC is used for projects smaller than $5 million in value nearly one-quarter of the time. These projects may be more akin to pure construction management, but the result is significant all the same. D-B/LB is data is nearly as we expect, with a low percentage of contract awards over $20 million. However, it would be expected that the ratio of D-B-B and D-B/LB would be reversed.

Table 1. Percentage of Project by Delivery Type and Award Value

Delivery Method	Sample Size	Contract Award Over $20M	Contract Award Under $20M	Contract Award Under $10M	Contract Award Under $5M
D-B-B	130	36%	64%	40%	28%
CM/GC	31	48%	52%	32%	23%
D-B/LB	37	16%	84%	70%	54%
D-B/BV	77	55%	45%	25%	14%
All Projects	275	40%	60%	39%	27%

Table 2. Project's Average Award Values by Delivery Type

Delivery Method	Sample Size	Average Contract Award	Minimum Contract Award	Maximum Contract Award	Standard Deviation
D-B-B	130	$20,075,495	$183,203	$252,052,326	$28,632,883
CM/GC	31	$36,774,468	$1,390,829	$235,936,100	$53,428,164
D-B/LB	37	$10,384,921	$69,108	$68,826,265	$14,755,108
D-B/BV	77	$42,954,212	$622,318	$357,760,287	$63,318,048
All Projects	275	$27,060,143	$69,108	$357,760,287	$44,514,385

Table 3. Small Project's Average Cost Growth by Delivery Type and Award Value*

Delivery Method	Over $20M		Under $20M		Under $10M		Under $5M	
	Sample Size	Cost Growth	Sample Size	Cost Growth	Sample Size	Cost Growth	Sample Size	Cost Growth
D-B-B	47	6.20%	83	3.40%	52	2.30%	36	1.00%
CM/GC	15	-0.20%	16	2.00%	10	1.30%	7	1.50%
D-B/LB	6	3.40%	31	3.20%	26	3.80%	20	3.80%
D-B/BV	42	4.40%	35	3.30%	19	2.20%	9	2.00%
All Projects	110	4.50%	165	3.20%	107	2.60%	72	2.00%

*Extreme outliers removed

Table 2 depicts a significant contract award range in D-B-B, D-B/BV, and CM/GC which suggests that all methods, which the exception of D-B/LB, are being used on projects ranging in monetary value from small resurfacing jobs to mega-projects. Table 2 also shows D-B-B and CM/GC having very similar maximum awards. D-B/LB is the only project delivery whose data is as we expect, as it appears to be almost exclusively used for smaller sized projects. These results suggest that there are variables other than monetary size driving agencies' choice of delivery method.

Table 3 depicts the project's average cost growths by delivery type and monetary size, but with very few statistically significant differences. Schedule growth findings are not presented as their findings resulted in no statistically significant inequalities nor any inequality trends to comment upon. Of the 48 total cost growth relationships, there were only 5 that were statistically significantly different at the 95% confidence level. They are as follows: CM/GC projects with an average award value over \$20M have a lower cost growth than CM/GC projects with an average award value under \$20M, \$10M, and \$5M; CM/GC projects with an average award value over \$20M have a lower cost growth than D-B-B projects with an average award value over \$20M; and D-B-B projects with an average award value under \$5M have a lower cost growth than D-B-B projects with an award value over \$20M.

The general lack of statistically significant inequalities suggests that there is no correlation between project delivery method, monetary award size, and performance factors. This suggests that any delivery method can be used with any project size with no negative impact to cost or schedule performance. This is an interesting finding, and supports the authors' belief that ACMs can be used on smaller projects with no negative affect to cost and schedule. Table 3 also suggests that D-B projects actually perform better for projects under \$20 million. Another significant finding is that, with the exception of D-B/LB, all of the project delivery methods perform incredibly well when used for projects under \$5 million. D-B/BV specifically becomes more advantageous as the project size decreases, which is counterintuitive to what we would expect. Table 3 also suggests that CM/GC performs exceptionally well on larger projects and D-B-B performs exceptionally poor, which is to be expected.

The statistically significant inequality relationships show that as the project size decreases, as does the construction intensity with minor exceptions. As this is not a significant finding, it will not be discussed. Of the 18 total award value cost growth relationships between project delivery models, 6 were found to be statistically different at the 95% confidence level and 1 at the 90% confidence level. These statistically significant construction intensity relationships inequalities between delivery methods of equal award value are as follows:

- *Over \$20 million:* D-B-B < D-B/BV and CM/GV, 95% confidence level
- *Over \$20 million:* D-B/LB < CM/GC, 90% confidence level
- *Under \$20 million:* CM/GC > D-B-B and D-B/LB, 95% confidence level
- *Under \$5 million:* CM/GC > D-B-B and D-B/BV, 95% confidence level

Construction intensity is defined by the average value of work performed per day spread out among the entire construction period, from the contract execution through the end of construction. This descriptive statistic is of importance as it depicts the project's delivery speed and therefore level of impact to the public [6]. Also to be noted is that D-B construction intensity may include the completion of the design which could incorrectly lower the construction intensity.

Table 4. Small Project's Average Construction Intensity by Delivery Type and Award Value

Delivery Method	Under \$20M		Under \$10M		Under \$5M	
	Sample Size	Const. Intensity	Sample Size	Const. Intensity	Sample Size	Const. Intensity
D-B-B	81	\$14,151	50	\$9,881	34	\$5,869
CM/GC	17	\$23,231	10	\$12,854	7	\$10,345
D-B/LB	30	\$13,018	25	\$10,975	19	\$9,464
D-B/BV	34	\$17,862	19	\$11,119	9	\$6,495
All Projects	162	\$15,673	104	\$10,656	69	\$7,394

Table 4 depicts CM/GC as having the largest construction intensity in comparison to all of the other delivery types. Based on previous studies of schedule duration [12] with all costs being equal, we would expect the intensity to increase as follows: D-B-B, CM/GC, D-B/LB, D-B/BV. As D-B/LB's average award value is significantly smaller than the other three models, it is expected that its intensity is less. However, it is unexpected that CM/GC would have a construction intensity greater than D-B. This result may be due to D-B's construction intensity including a portion of the design duration.

Another item of note is the relatively high intensity of D-B/LB on the projects with award values less than $5 million. D-B/LB does not perform well in comparison to the other delivery models within the construction intensity performance metric with the exception of these very small projects. This suggests that the low bid procurement approach is superior when D-B is desired, project award is less than $5 million, and public impact mitigation is desired.

5. Conclusions

This study's results challenge the common perception in the construction industry that ACMs are only appropriate for large-scale projects. Nearly half of the CM/GC and D-B/BV projects in this study were under $20 million in value. Concerning performance factors, no statistically significant difference in cost and schedule growth was found between delivery models within the less than $20M, $10M, and $5M contract award categories. The only finding correlating size to a delivery model is that CM/GC's cost growth for projects over $20 million was statistically significantly less than D-B-B and D-B/BV. Although this suggests large projects are most successful when CM/GC is used, the descriptive statistics depict a significant contract award range in D-B-B, D-B/BV, and CM/GC which suggests that these methods are being used on projects ranging in monetary value from small resurfacing jobs to the mega-projects.

Per construction intensity findings, CM/GC and D-B/BV have the fastest delivery speeds of the small projects. This is of importance when a greater inconvenience over a shorter period of time is desired. Often, this is preferred by the public as documented with the UDOT I-15 reconstruction job, completed in 2001. UDOT received an 84% affirmative evaluation from the public on the I-15 project due strongly to the delivery speed of the D-B project [20]. The fact that this research shows CM/GC having a larger construction intensity may be due to D-B's construction duration including a portion of the design duration.

These findings are proof that ACMs are not only being used on small projects, they are performing as well as the traditional model. These findings also suggest that project characteristics other than monetary size correlate to favorable performance of different project delivery methods. The authors are performing correlation analyses of these characteristics such as complexity, facility type, project type, etc. to favorable performance per delivery model but as these correlations are not within the purview of this paper, it will not be discussed. From the findings within this paper, the authors believe that agencies must always consider alternative project models for their projects. D-B and CM/GC have proven to be viable means for governmental agencies to expedite small highway projects without introducing cost or schedule growth.

The largest limitation of this study is the inability to achieve statistically significant differences between the relationships of project delivery methods performance factors. This may be due to the fact that the descriptive statistics are not different between delivery methods, but is more likely due to database size. Although this is one of the largest databases reviewing the performance metrics of ACMs, it still may not be large enough when the data is decomposed to examine small projects. The sample size of CM/GC is especially small due to the relatively recent use of CM/GC as a delivery method across the country. The reader should also understand that, other than projects performed in Utah and Arizona, all of the CM/GC projects are the agency's first or second use of CM/GC. Therefore, the data may be unintentionally skewed due to the learning curve associated with the use of CM/GC.

It would be of interest to know the managerial differences of agency's between not only project delivery methods but also monetary award values. Future research would include acquiring performance metrics of projects and comparing them to managerial styles acquired through case studies and interviews. This may result in not only an understanding of the best managerial styles but perhaps successful managerial styles not distributed throughout the transportation community.

The authors of this research believe the use of ACMs on small projects will continue into the future. It would be beneficial for this study to be performed again after the duration of a typical project has finished, around three to six years. Adding the newly completed projects would increase the robustness of the database, potentially remove the impacts caused by the CM/GC projects that were the agency's first or second experience, and allow for more statistically significant findings. As this is the first research to report findings of frequent and successful use of ACMs on small projects, it would be beneficial to support this research's findings through future research.

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